MATERIALS AND METHODS

Materials

1. Topographic map of the study area in Phu Khieo Wildlife Sanctuary, Chaiyaphum Province, at scale 1: 50,000, map sheet no. 5341IV
2. Landsat-7 ETM+ Satellite image of the study area, scale 1:50,000, year 2000
3. GPS-Receiver
4. Hand compasses
5. Wrist watches
6. Binoculars
7. Camera and lens
8. Meter tape and diameter tape
9. Data tables, waterproof notebooks and stationery
10. Sets of computers
11. GIS software programs and statistic program

Methods

1. Preliminary survey

At the start of the study a preliminary survey was conducted to select a suitable area at Huai Mai Sot Yai for the collection of gibbon data. In addition, this period served to test the observational methods for feasibility. The preliminary survey consisted of selecting spots for the listening post in the study area and the selection of a white-handed gibbon family for direct behavioral observation.

1.1 Listening posts were identified to locate the coordinates of white-handed gibbon groups. Coordinates were obtained from the morning calls via triangulation. Whenever white-handed gibbons called, the compass direction, time, estimated distance, and type of call were recorded. All of this information was plotted in the topographic map to locate the coordinates of the gibbons.

1.2 A white-handed gibbon family was selected to study their ecology, activity, and home range. In order to collect reliable data and to avoid problems related to the gibbons fleeing from the observer, a group that was already semi-habituated was selected. Habituation increased further during this study.

2. Data collection:

This research was conducted from November 2003 until October 2004 (12 months). The collected data included three types namely the ecology and behavior of white-handed gibbons, their population density and a habitat suitability map.

2.1 Ecology and behavior studies: I directly observed a representative gibbon family (called G1) by the same method as Muangkhum (2001). I memorized characteristics of the members of G1 in order not to confuse the members with other groups. Each individual had different characteristics in terms of the hair colour, the size of the body, sex and the width of the white hair border around the face. I noted down all types of behavior of each individual every 20 minutes (scan sampling; Altmann 1974). The observations were conducted from 06:00 h until 17:00 h (11 hours per day) over a period of 12 months. The collected data included the gibbons' location (GPS coordinates), the behavior of each member, the types of food and the parts of food plants if they had been eating. Because gibbons used hands and fingers for picking and selecting each piece of food it was sometimes difficult to keep good specimens of food plants for taking photos. Hence, the specimens of food plants were often collected after following G1 in order to identify and take photos. I collected the gibbon's locations or its coordinates by a GPS-receiver. Furthermore, there are temporary grid squares (50x50 meters) in the Huai Mai Sot Yai area created by the research project "Behavior and Ecology of Macaque and Langur Monkeys" by Dr. Andreas Koenig. These temporary grid squares have a geographic coordinate. A map of all the temporary grid squares shows such geographic coordinates. So, if the GPS could not detect satellites, I noted the grid square in the forest and I could find the gibbons' locations from the number of the grid squares. If possible I followed the gibbons until they went to sleep. The data collection was at least 2-4 days per month for the whole 12 months.

2.2 Population density study: I used 2 methods of data collection in order to analyze population density of white-handed gibbon in Huai Mai Sot Yai area. Those 2 methods were the auditory method and transect method. Both methods are using triangulation manner.

2.2.1 Auditory method: This means to find the coordinates of gibbons by using triangulation of the gibbon's loud song (Brockelman and Srikosamatara, 1993; Brockelman, 2003; Srikosamatara, 1980). This method has been used to survey primates in the family of Hylobatidae, because they all have such loud and regular vocalization. The data was obtained from gibbon's calling, and was composed of the time of the calling, the compass direction, the type of calling and the distance; i.e. an estimate of the distance between the observer and the gibbons. The data was collected starting at ca. 5:30-6.00 am until 11:30-12:00 am in each day. A minimum of 2 days with listening posts was conducted each month over a period of 12 months. The listening posts were placed on hilltops for a clear perception of the gibbon call. In order to triangulate, there were two listeners in different places, which were apart at least 500 meters (Brockelman, 2003; Srikosamatara, 1980). We listened at the same time to locate the gibbons by the method of triangulation. Because gibbons are territorial, vocalizations from one specific area indicate one gibbon group. The listening area was created by a fixed range of 2 kilometers around the listening posts (Brockelman, 2003; Srikosamatara, 1980). All of the information was plotted on a topographic map (1:25,000) and the density of gibbon groups in the area was calculated.

2.2.2 Transect and trail surveyed: These data were collected surveying the area along wildlife trails at Huai Mai Sot Yai. This transect was surveyed for approximately 26 km in length. When a gibbon was seen, I recorded its GPS-location. In addition, when I heard gibbons calling, I noted the time, compass direction and the type of sound and recorded my listening location via the GPS-receiver. In addition, I noted all the information of gibbon calls from my listening locations. After that, I plotted the listening locations in the topographic map (scale 1:25,000) and located the gibbon locations by triangulation method from the information of all data.

2.3 Habitat suitability map study: A habitat map was built based on some independent environmental factors that are parts of the habitat of white-handed gibbons at Huai Mai Sot Yai. I used 2 methods of data collection in order to find the gibbon locations such as transects and the auditory method. The data collection of both methods was same as described above for population density. Both methods located gibbon coordinates by triangulation. In addition to the gibbons' location from triangulation, there were gibbons' locations from encounters and record GPS-locations while collected data by the transect method and auditory method. White-handed gibbon's locations were collected for 12 months.

3. Data analysis

This study had three main topics, accordingly I analyzed data in terms of ecology and behavior, population density estimation and habitat suitability map analysis.

3.1 Ecology and behavior:

3.1.1 Behavior: Data of gibbon's behavior were categorized into 9 types namely locomotion (L), feeding (F), grooming (G), resting (R), vocalization (V), sleeping (S), playing (P), aggression (A) and other behavior (O). In addition, I separated the behavioral data of the adults and juveniles and computed the percentage for each behavior. Then I combined the observed data for each behavior in each observed period of the day and computed the percentage of the behaviors in each observed period.

3.1.2 Home range of the focal family and its neighbours: The G1 family's home range was produced from the location data. All gibbons' GPS-locations were down-loaded into a computer and analyzed using the program Mapsource 5.4. In addition, the data from the temporary grid squares were changed to the geographic coordinate's data. All the coordinate data for the whole year was divided into 2 seasons; the dry season (Nov.2003-Mar.2004) and the wet season (Apr.-Oct.2004). The gibbons' home ranges in the dry and wet seasons were then generated by using the program GIS software program. I used the Kernel Home Range Method (50% and 95%), which was recommended by Worton (1989) and Seaman and Powell (1996).

3.1.3 Food: After collecting specimens of food plants in the field, I took photos and I identified the species of food plants. If I could not identify the species, I prepared dry specimens for further identification or compared it to the known specimens at the herbarium of the DNP. For the analysis of the diet of the gibbons, the species of all food plants were combined into the whole year, but also separated into the dry season and the wet season. In addition, all food plants were analyzed in terms of the numbers of species, the family of the most important food plants, and the percentage of food plants. The parts of the food plants that were used by the gibbons were subdivided into items such as ripe fruits, unripe fruits, young leaves, flowers, and shoots. The amount of each of these items in the gibbon diet was calculated as percentage.

3.1.4 Plant community: I constructed 2 sample plots of 20x50 meters in the study area. The trees, which had a girth above 13 cm, were measured and recorded with girth and height. A selection of a 10x50 meters plot in the sample plots was profiled to show the structure of the forest. The trees in the profiled sample plots, which had a girth above 13 cm, were measured with the girth, the size of the crown cover, the total height, the height of the first branch, and the position in the sample plot (x, y coordinates). After that, all these data were used to draw the profile diagram of the dry evergreen forest and the hill evergreen forest.

3.2 Population density estimation: For the analysis of population density I used data from 2 methods of data collection such as gibbons' locations by transect surveyed and the locations of gibbons' family by the auditory method. Gibbons' locations were plotted from the data of auditory method in each month into a topographic map (1:25,000, one month per one map). Next, the gibbons' locations from all topographic maps (12 months) were summarized into one map. This map showed the locations of gibbons' family in Huai Mai Sot Yai area. Afterwards, I summarized the numbers of gibbons' locations by transect surveyed and the numbers of the locations of gibbon families in order to calculate population density. The boundary of the study area was created by a fixed range of 2 kilometers from the listening posts. Within this area used for the calculation of the gibbons' density there were the dry evergreen forest and hill evergreen forest. Because of white-handed gibbon spend most of the day in the tree, the density of crown cover is important both in terms of the gibbons' movement and their distribution. Most likely because it has a low density of crown cover, the dry dipterocarp forest is seldomly used by white-handed gibbons. Therefore, in this study I used the area of dry and hill evergreen forest to calculate the density of gibbons, but I did not include the dry dipterocarp forest. After I knew the average number of members in a family, I could calculate the total population density by the following equations;

$$\text{Population density}\left(\text{families}/\text{km}^2\right) = \frac{\text{Number of families}}{\text{Area}\left(\text{km}^2\right)}$$

$$\text{Number of gibbons}\left(\text{individuals}\right) = \text{Averaging number of members in family} \times \text{Number of families}$$

$$\text{Populaton density}\left(\text{individuals}/\text{km}^2\right) = \frac{\text{Number of gibbon}\left(\text{individuals}\right)}{\text{Area}\left(\text{km}^2\right)}$$

3.3 Habitat suitability map analysis: For the habitat suitability analysis I used all coordinate data of white-handed gibbons producing a habitat suitability map of the white-handed gibbon at Huai Mai Sot Yai. In addition, this habitat suitability map was analyzed statistically (logistic regression analysis). I produced the habitat suitability map following the procedure outline in figure 4.

3.3.1 In order to prepare the coordinates of the gibbon locations (GPS-location), the geo-coordinated data were converted to a shape file. After that 20% of gibbon locations were randomly selected to check for accuracy later and the remaining 80% of all data was used to generate the predictive model.

3.3.2 In order to prepare independent environmental factors and to analyze the relation to the dependent factor of gibbon distribution and location, I used the coordinates for gibbons, which were already prepared previously. The independent environmental factors for this analysis consisted of forest type, distance to roads, distance to streams, DEM and slope. All independent environmental factors were converted to raster type (20 x 20 m).

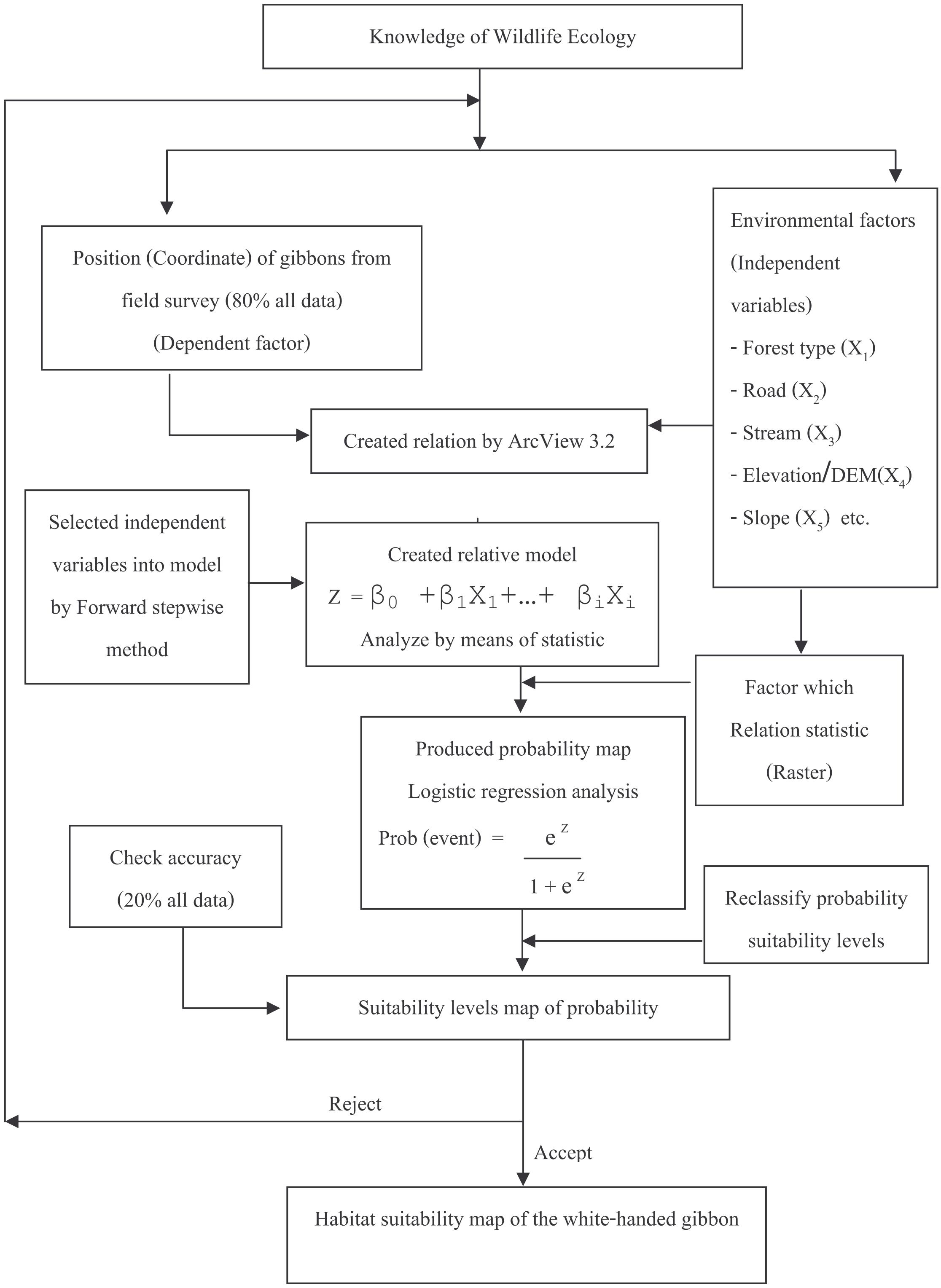

Figure 4 Flowchart of study and analysis for habitat suitability map of the white-handed gibbon.

3.3.3 I created logistic multiple regression models for the relation of presence-absence of gibbons in relation to each environmental factor.

a. Relation between gibbons coordinate's and environmental factor in terms of distance: This type of data asks for the relation between the gibbons coordinate's and distance to roads or streams. In other words, I converted the gibbon locations and the location of the road or streams to distance.

b. Relation between gibbons coordinate's and environmental factor in terms of position: These data relate to the forest type, digital elevation model (DEM) and slope in the given form. That is to say, in which forest type, DEM and slope were the gibbons found at the time when they were recorded.

3.3.4 For the analysis of all relational data from the logistic regression function model a forward stepwise method was used. Results were environmental factors, which were related with gibbons in a statistical manner. For such a model Vanichbancha (2001) recommended the following equation:

$$Z = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \ldots\ldots + \beta_i x_i$$ …………Equation 1

Where, Z	=	linear combination (dependent variable)
X	=	independent variable
β_0, β_1	=	population regression coefficients

3.3.5 To convert the environmental factors in equation1 to grid files (20 x20 meters) in GIS, I computed the logistic regression function from the equation below;

$$P(x) = \frac{e^Z}{1 + e^Z}$$ …………Equation 2

Where, P(X)	=	conditional probability
e	=	exponential function
Z	=	linear combination

3.3.6 The probability scores vary between 0 – 1. Later these scores were reclassified into three classes of suitability; most suitability, moderate suitability and less suitability. The probability scores were reclassified using the natural breaks method.

3.3.7 To verify the accuracy of the results I overlaid the randomly selected coordinates of gibbons (20% of all field data) with the habitat suitability map. Then I computed the percentage of accuracy by the number of coordinate data within and outside the area of the highest suitability (most suitability).

3.4 Estimation of the population density from habitat suitability: Once I knew the size of the most suitable habitats and the home range of white-handed gibbon, I calculated the population density of white-handed gibbon as follows:

$$\text{Estimate number of families} = \frac{\text{Mostly habitat suitability}\left(\text{km}^2\right)}{\text{Core area of WHG's habitat}\left(\text{km}^2\right)}$$

$$\text{Population density}\left(\text{families}/\text{km}^2\right) = \frac{\text{Estimate number of families}}{\text{Study area}\left(\text{km}^2\right)}$$

$$\text{Population density}\left(\text{individuals}/\text{km}^2\right) = \text{Population density}\left(\text{families}/\text{km}^2\right) \times \text{Mean of members family}$$